possible for a cubic foot of air at 80° F. to contain 10.93 grains; hence, by dividing the actual amount, 7.99, by the possible amount 10.93, I obtain for the relative humidity 73 per cent. On the other hand, suppose that without changing the actual amount of vapor in the air I cool down some of the original moist air from 80° F. to 70° F. The above table shows that at 70° F. our 7.99 grains would be sufficient to saturate a cubic foot of air. Hence the air has now reached the dew-point, and the moment the temperature falls below this point condensation of the vapor will begin and will continue so long as the temperature continues to fall. When the temperature has reached 60° F. 2.24 grains of vapor will have been condensed from each original foot of air.

This condensed vapor will appear either in the form of fog. snow, rain, or dew, depending upon other conditions. Condensation is essentially the rushing together of the surplus molecules of aqueous vapor, forming small drops of water or crystals of ice, which become visible as fog or cloud. The tendency of these minute drops is to fall to the ground, but the upward air currents are generally quite sufficient to sustain them until the drops grow to a larger size, when they are precipitated as rain. When the condensation is very rapid the upward currents are also rapid and the raindrops are likely to be large. Of course, snow is formed only when the temperature of condensation, namely, the dew-point, is below freezing.

Precipitation, therefore, depends upon a falling temperature, and the primary question is how may this be brought about. The most common and effective ways and in the order of increasing importance are: (1) cooling by contact with cooler bodies; (2) mixture with air of lower temperature; (3) loss of heat by radiation; (4) loss of temperature by the utilization of heat in work.

1. The direct contact of warm, moist air with a cold surface, it does not matter whether it be a glass containing cold water or a mountain covered with snow, must result in giving up heat to the cold object, which thereby becomes warmer. Now, the quantity of heat that can be taken up by a cold mountain side is very slight. A little dew may be formed on the rocks, but this represents the extent of its power to condense moisture out of the air.

2. When equal parts of cold and warm air are mixed together, both being saturated, a very slight cloud or haze is formed, due to the fact that the saturated warm air contains a little more moisture than was necessary to saturate the mixture, but this slight haze is the extent of the precipitation that can be formed in this way.

3. When the air is nearly saturated in the daytime, it is apt to cool below its dew-point during the following nighttime; there is thus formed a thin layer of fog near the surface of the earth, or of stratus cloud a few yards above the surface, or perhaps alto-stratus a few thousand feet above that. In either case, the lower side of the fog or cloud receives heat from the earth, while it is only the upper side that cools by radiation into space. During long nights this cooling may produce a deep layer of fog, or a thick layer of cloud, and from the upper surface of these there may fall a light, drizzling rain; but this is the maximum extent of the influence of radiation.

4. The conversion of the molecular energy that we call heat into the movement of large masses that we call work is the most important method of cooling. Whenever a given volume of air flows into a region where the barometric pressure is less, it expands and in this expansion must push aside the air immediately surrounding it. This is the work that is done, and it is exactly equivalent to the amount of heat energy that is consumed. Thus, the steam in a boiler flows into the cylinder and pushes the piston ahead, by doing so it does work and cools off. When the safety valve of the boiler is open, the steam rushes out with great force, expands greatly in volume and cools. In fact, it falls from the temperature within the boiler to the temperature of the open air. When this process takes place quickly and no other heat comes in to disturb the conditions, this is called adiabatic expansion or adiabatic cooling. Whenever a mass of moist air is pushed by the wind over a hill or mountain it expands as it ascends because the pressure diminishes with altitude, and its temperature may easily be reduced below the dew-point, so that by cooling it forms a cloud and by still further cooling may form rain. Ascending air, under the ordinary barometric conditions, must cool at the rate of 1° C. for about 100 meters of ascent, or 1° F. for 183 feet of ascent. Thus, suppose our cubic foot of air at 80° F. to be lifted 1830 feet it would then have cooled to a temperature of 70° F. and be saturated; should it be carried still higher condensation must occur. It is evident that the height to which a body of air must be raised before condensation begins depends upon both the temperature and the humidity of the air at sea level. Hence in regions of high humidity comparatively low mountains may be important agents in bringing about rainfall, whereas in regions of low humidity very high mountains may have little influence. There are mountains which rise to such a height that the air about their summits has a temperature of freezing or less, so that the mountains have a crown of perpetual snow.

The office of mountains is to force the warm moist surface wind into higher regions whereby it is expanded and cooled, and in this way only do they bring about condensation and precipitation. A single peak, even if very high, may not be very effective, as the air currents may pass around it instead of over it, and will merely form clouds in the region of slightly diminished pressure and upward rising currents on the leeward side of the peak. But in the case of a mountain range the whole mass of air driven by the wind must pass over and must, therefore, rise to higher regions in order to do so. The mistake should not be made of supposing that the mountain "acts as a condenser" in the same sense that a blade of grass when chilled by radiation, cools the air in contact with it and accumulates dew. It is evident that if a mountain did act in this way the moisture would be deposited on it in the same manner as dew or frost is deposited on the grass, or on the cool exterior of a glassful of ice water, and the precipitation would not appear as a cloud or as rain. In general, the mountains act merely as obstacles to the currents of air. A mountain may be very effective in the formation of clouds without having much influence on the rainfall. The region or side of the mountain upon which the rain will fall depends almost entirely on the direction from which the moist wind comes. In some cases the wind deflected upward by the mountain may continue rising for a short distance beyond the mountain, so that the rain may fall to the leeward rather than on the mountain itself.

CLIMATE AND CORN.

By H. B. WREN, U. S. Weather Bureau.

The weather exerts a tacit, though relentless, tyranny over the labor and the thought of the agriculturist. The probable influences of the present and prospective weather upon the growing crops are seldom absent from his mind. But science teaches that climate is rhythmic, not capricious. Laplace has shown that the mean temperature of the mass of the earth can not have changed in any appreciable measure during the entire period of astronomical calculation and that while the planetary movements remain as at present no such change can occur. "Astronomical permanency," he says, "implies an absolute fixedness of the quantity of heat for the mass of the earth." And the sun's heat is the leading element of climate, all other conditions depend in the long run upon that. Hence, the sun's heat being constant, all the changes we observe are periodic as regards the astronomical units, the day and the year; and nonperiodic in all other cases, the averages returning always to a line of absolute permanency.

Climate is the average of seasonal atmospheric conditions, and as corn is an annual plant, these fluctuating seasonal factors must affect its growth. The crop season is in fact the climatic unit with respect to this cereal. No season exactly repeats itself; there are perturbations within relatively narrow limits; the plant strives perpetually to adjust itself to perfect correspondence with its environment. As this environment, that is, climate and food supply, vibrates now one way, now another about a fixed mean, the consequent variations of the plant will be compensatory, and so there should be no final permanent modification of the plant in a given locality. The tendency in the long run is toward a more and more perfect correspondence with environment, toward what Spencer calls the one essential to perfect life.

That the study of climate, as well as soil, in all its bearings upon the great American staple is as profitable as any that engages the attention of the Government is shown by the results already attained, but still more by certain economic considerations. It is a surprising, even startling, fact that the average yield of corn in the United States is only about twenty-three bushels per acre, while a prize yield of more than two hundred bushels is well authenticated. The world is just beginning to appreciate the value of corn as a food, and in the new commercial era that is dawning upon our country it will devolve upon us to supply a large part of the world's demand for this cereal. No valid reason is apparent why the average annual yield should not be twice or thrice what it now is.

Aside from its direct control of the amount and quality of the crop, climatic variations, by vitiating experience, impede agricultural progress. This fact is most apparent in the agricultural history of a new country, where experience acquired in one section is in many cases not only useless, but positively pernicious when applied to a distant section. In the United States millions of dollars have been lost through the efforts of new settlers to learn by experience the climatic peculiarities of their adopted home. It is the province of agricultural science to teach us how to profit by the experience that has been so dearly bought in the past.

Agricultural climatology considers the relations between the meteorological elements measured in terms of plant development. As intimate as these relations are known to be, and as interesting and promising a field as their study is known to offer, it is rather surprising that no adequate organized effort has yet been expended in this direction. But we are coming to see that the very fact of this intimate reciprocal dependence may be turned to advantage, and that by methods of correlation the facts of each science may be made to illumine the other.

The laws of biological and of meteorological phenomena separately considered are extremely subtle and complex, and any attempt to study them in their manifold reciprocal relations is sufficiently difficult to deter any but the best equipped and most zealous students. This difficulty of properly interpreting the separate effects upon vegetation of heat, light, moisture, and the gases of the atmosphere is enhanced by the fact that a change in one meteorological condition ordinarily disturbs all the other elements. For example, rain is accompanied by cloudiness, decrease in light and heat, and, it may be, by an increase of warmth in the soil, if the rain be a warm one.

Extended and elaborate meteorological observations have been conducted in this country and in Europe, but instruments measure only detached elements of climate; plants alone record its composite or cumulative effects. Hence, the insistence on the part of leading agricultural scientists that climate should be studied in terms of plant life. Such study is termed phenology, and while it has led to some valuable generalizations, the fragmentary character of the data vitiates many of its conclusions. It appears that in the past phenologists have given the element of heat undue, if not almost exclusive, weight. It is becoming more and more evident that the real function and value of light have been neglected and undervalued. A fundamental theory which has been held by botanists for more than a century is, briefly, that a certain life event takes place in any species whenever that species has been exposed to a certain sum total of heat, which is called the physiological constant or thermal constant. In harmony with this theory, Blodgett, in his Climatology of the United States, says with regard to corn that its period of growth is precisely proportional to the abruptness of the temperature curve; that its unusual elasticity of constitution admits it to all regions where the temperature reaches a certain point, however brief the duration of this warm period may be. He defines the extreme northern limits of Indian corn as coincident with the isotherm of 67° for July, though a somewhat higher mean for one summer month is required, and he attributes the increase of productiveness at the north mainly to "the hasty growth, the excess of heat while it lasts, and the hastened ripening period." The seemingly insignificant item of a deficiency of two degrees on the mean of a single summer month practically excludes this crop from the British Isles, where it is grown, when grown at all, only as a forage crop, seldom maturing any grain. This statement of the subject has been for fifty years the popular and the current theory. Temperature being the most easily measured of the solar manifestations, it has quite naturally been regarded as the dominant one. Then, too, the rudimentary state of climatology made necessary such a simplification as is afforded by the consideration of heat alone.

The trend of recent opinion is summarized by Professor Abbe in his extensive manuscript report of June, 1891, on the Relations of Climate and Crops, where, after reviewing the investigations of Tisserand, he concludes:

> That the temperature of the air has apparently little to do, in and of itself, with the duration of time from sowing to ripening, but that this depends principally on the sunshine. The temperature of the air controls the chemical composition of the seed, but the effective sunshine seems to be the productive climatic element; it furnishes the total energy at the disposal of the plant, but it is also the one least studied and understood.

Professor Sturtevant, of New York, from tests with 128 varieties, concludes that "actinism has an influence scarcely secondary to temperature."

So it would seem wise in the light of recent study to attribute much of the hostility of a climate like that of England to the greater degree of cloudiness, and the congeniality of the climate of our western States to the habitually clear skies of summer.

In discussing climate and corn it will be convenient to treat their relations first historically and then analytically; a cursory glance at the more evident accumulated results of climatic modification and limitation will prepare the way for an outline of the individual factors that constitute environment and the principles that govern the life of the plant.

The original home of corn, or maize, is now quite certainly known to have been in central Mexico, and hence it is the only one of our cereals that is indigenous to the New World. It has been so long and so thoroughly domesticated that no truly wild varieties are known. In geographical range and elasticity of habit it probably surpasses every other cultivated plant. From its original tropical home it has spread to the temperate as well as the tropical regions of the world. Introduced into Europe soon after the conquest of Mexico, it finds a genial home only in the warm valleys of the south and central portions of that continent; it is extensively grown in Africa, and in India it thrives everywhere throughout the hill country; it appears to flourish as well in the temperate as the tropical regions, and at altitudes of from sea level to 7,000 feet or more.

Corn is, however, as it has always been and will undoubtedly remain, a distinctive and characteristic American product. It is cultivated from Canada to Patagonia, over 7,000 miles of latitude. It has been known to ripen as far north as 63° and has been found a profitable crop in latitude 51° north. In response to the multifarious conditions which this great range imposes, countless varieties have been developed, there being over 200 in the United States alone. It is interesting to consider some of the extremes of variation as exhibited by the plant and the ear, variations that have their origin ultimately in climate and acclimatization. The matured plant ranges from 2 to 22 feet in height; stalks as tall as 30 feet have been found in the West Indies, and a normal plant 18 inches in height has been known to mature perfect ears. Ears have been known as small as 1½ inches and as great as 16 inches in length. The number of rows of grains to the ear ranges from 6 to 40 or more. The period for growth and maturity varies from six weeks to seven months. Besides the usual colors, white, yellow, and red, the grain is also found to be violet, purple, blue, slate, black, and variegated. Incidentally it may be said that color is by some considered the most stable feature, and red corn is believed to possess a greater fixity of type than any other. Along with these remarkable extremes in size, a corresponding range of total yield is found; though the total crop does not, of course, depend directly upon the size of the ears or of the kernels. Nevertheless there is a very wide disparity in productiveness depending upon climatic irregularities independent of soil fertility or of food supply. Both in quality and productiveness corn has improved to a marked degree in the higher latitudes to which it has spread. Indeed, it is a rather striking fact that the maximum yield is found near the northern limit of its cultivation. The weight of the grain per bushel is also usually greater at the north. Corn thus presents a rather unique instance of a plant which by culture and acclimatization has come to thrive better in an alien home. This result will be seen later to depend upon a general law.

In no other section of the world, however, does the yield of corn in any way equal that of the corn belt of the United States, or the seven corn surplus States from Ohio to Nebraska and Kansas, inclusive. To be sure corn is grown, and one or more of its many varieties may thrive, in every State and Territory of the Union, yet in 1899 six States raised nearly 60 per cent of the crop, and twenty-five States now produce 95 per cent of the total yield. As an illustration of the great acreage devoted to corn, it has been said that the eleven cotton States as a whole give a greater area to corn than to cotton.

The better adaptability of the high temperate regions to corn is not altogether an unmitigated advantage. In the United States the seasonal limits preclude the possibility of more than one crop a year, though in southern California, with the aid of irrigation, two crops in one year have been raised, and in most tropical regions two and sometimes three crops a year are regularly grown on the same ground. Not only does the change in latitude modify, but transportation in longitude produces effects almost as notable. According to Darwin, American white dent corn cultivated in Germany for three years without selection was greatly reduced in size, lost its dented character, and assumed a yellow color common to corn in that country. Changes almost as marked have occurred in a few generations in corn from one part of the United States when removed to a distant part. According to Professor Beal a soft gourd corn from Texas, after cultivation in Louisiana for twelve years, became a hard flint with larger cob. An 8-rowed flint corn from the north, after seven years' cultivation without selection in Ohio, became much dented and the number of rows increased from 12 to 20.

The ratio of weight or size of total plant to grain varies according to somewhat definite laws. In the United States there is, generally speaking, a uniform decrease in the height of the plant from 12 feet in the Gulf States to 6 feet in Canada. Accompanying this dwarfing of the plant by the progressive increase of cold, there is, up to a certain latitude, an almost equal increase of grain. Hence, there would seem to exist for any given variety a certain fixed optimum ratio between plant and grain; this ratio has not been determined, however, and seems to have received but little attention. Another concomitant, or it may be result of this dwarfing by cold, is a prominent tendency of the dwarfed varieties to develop suckers. This tendency may also appear locally whenever the growth of the stem is retarded, and is probably due to sustained activity of the roots and the subterranean portions of the stem, which retaining the higher temperature of the soil, promote the development of new stems. Dwarfing at the north is further accompanied by a shortening of the internodes of the stem and an increased leaf surface. This increase of foliage in high latitudes is undoubtedly due, in large part, to the necessity for more rapid assimilation in the shorter season, the special function of the leaf being, as we shall see, to absorb the energy of the sun's light and to control, by means of respiration, the food supply and the water content of the plant. Regarding the differences in composition of the grain but little of a conclusive nature is established; as with many other changes this is masked by changes in the food supply depending on the chemical activities of the soil, which activities depend in turn upon the climate. From an economic basis, perhaps the most conspicuous and certainly the most valuable feature of the corn plant is its elasticity with respect to the length of the period of growth: the varieties cultivated in the United States require at the south from one hundred to one hundred and seventy days for the best yield, while Blodgett mentions, in the valley of the Red River of the North, varieties that mature in sixty days.

Turning now to an analytical survey of the separate factors that constitute climate and their individual effects on the plant and on seed, brevity demands that all reference to methods and experiments be omitted and that only conclusions be stated. Introductory to this survey there will be given a review of the relations of the plant to its environment in general, and then of the means and methods of its response and adjustment to this environment, or what is termed the physiology of the plant. All that can be undertaken here is a compilation and a classification of results, and while the general subject is the relation of climate and corn, many of the statements that follow are generalizations that apply as aptly to other crops. In view of the difficulty of separating the individual from the combined effects of the meteorological elements, and the paucity of reliable data, this treatment will necessarily be fragmentary.

The effects of climate on corn may be appropriately classified as immediate, intermediate, and incidental.

Professor Storer has tersely and beautifully said that the prime object of agriculture is to collect for purposes of human aggrandizement as much as may be possible of the energy that comes from the sun in the form of light and heat. Now the working capacity of sunshine is, according to Kelvin, one-horse power for every 7 square feet of surface. Measured by the standards of mechanics, how inefficient and wasteful an engine is our agriculture at its best. The atmosphere is directly the source of 95 per cent of the material in the total plant and of 98 per cent of the matter in the grain of corn. The plant is an elaborate machine that absorbs and transforms energy, utilizing solar radiation to digest carbon dioxide in the leaves and to combine into vegetable organs and tissues the gases of the air with the elements supplied by the soil. When we remember that the amount of energy available, the food supply, and, consequently, the amount of matter stored, all depend directly upon meteorological conditions, we realize how overwhelming is the influence of climate.

A grain of corn once matured is as inert as a pebble until heat and moisture are applied; then a sprout and a root appear, each for a separate function, the one for absorbing etherial waves, the other for absorbing water. In addition to heat and moisture, oxygen is absolutely essential to germination, as well as to all subsequent growth. The importance of moisture will be appreciated when we recall that water performs at least four distinct offices: first, directly as a food, being united in the leaves with carbon to form the carbohydrates; second, as a solvent for the nutritive matters in the soil; third, as the vehicle which transports the soluble food through the roots and stems to the leaves; and, finally, as a cooling device, since, through evaporation, water largely controls the temperature of the plant. The "free water of vegetation," as it is called, or the water of the juices, comprises from 70 to 90 per cent of corn in the fodder stage, while the "combined water of vegetation," or the water that remains after the plant is air-dried, is 12 per cent in a kernel of corn.

The immediate effects of climate will be better understood by glancing first at its intermediate effects through the medium of the soil and through the food suppy. Climate originates soil and all the capacities of the earth for tillage, and it is at the same time more than soil or tillage. For in a truly "good year" the worst tilled soil returns a more bountiful harvest than it is possible with all our industry to extort from the best tilled soil in a "bad year." The oasis differs from the desert only in the item of water supply, and a given climate does not result primarily from the nature of the earth's surface; on the contrary, that surface is determined almost wholly by climate. The agencies that produce, and are producing arable areas from the seemingly impervious and indurate rocks, must continue their action perennially if the soil is to maintain itself. Indeed, the reverse metamorphosis is constantly at work. The greater part of the known rock formations were once in the form of soil, and chemical, physical, and even vital forces are continually engaged in the work of rock making, as well as rock breaking, so that an important office of agriculture is to oppose this cyclic law of nature, and to counteract the retrogressive tendency from soil to rock.

Primarily, the soil is a reservoir of moisture and plant food; but hardly secondary is its office as a vast laboratory, wherein during the warmer seasons, countless complex chemical agencies and numberless microscopic organisms operate unceasingly. Indeed, the relations of climate to the plant through the medium of the soil are so intimate and vital that no just idea of their importance can be given here. These relations may be classed as physical, chemical, and biological.

The physical texture of the soil determines its conductivity for heat and its content of water and air, both of which in proper proportions are essential to the chemical and biological functions. Moreover, the water content, through its power to absorb, transform, and conserve radiant energy, controls the temperature of the soil. Finally, soil temperature is far more effective than the temperature of the air. Heat is well known to accelerate diffusion, solution, osmotic action, and evaporation. Now these physical processes are precisely those that perform the chief, almost the entire work involved in plant nutrition and growth. Hence, a high soil temperature is essential not only for the life of the plant itself but also for the ventilation and the life of the soil, a healthy soil being very appropriately called a living mass. On an average, 40 per cent of the radiant energy incident on the soil is absorbed, conducted downward, and stored in the form of heat, 60 per cent being lost to the soil by reflection, radiation, and evaporation. The more water a given volume of soil contains at a given temperature the greater its latent heat. If the sun impart equal quantities of heat to equal volumes of sand, clay, humus, and water, then for each degree of rise in temperature of the water the humus will rise over 2°, the clay about 4°, the sand about 5°. Thus, on account of the high specific heat of water, with a normal amount of water in the soil, the effect is to retard the warming of the soil in the spring; but when a wet soil is once heated it is, of course, a great reservoir of energy. Again, by virtue of this property of high specific heat, water in the form of warm rain is a very fertile source of heat for the use of the crop. On the other hand, cold rains and the melting snows of spring are equally pernicious from this point of view. The work of evaporation in maintaining the ground at a moderate temperature under the fierce sun of summer is evident from the consideration that the evaporation of 1 pound of water from 1 cubic foot of soil will reduce the mean temperature of that soil by about 10°. Actual measurements confirm this theoretical conclusion by showing that during the summer months the average temperature of the 3 inches of soil nearest the surface is as much as 14° lower than that of the air. This difference between the temperature of a moist soil and the air above it is augmented by any condition that increases evaporation; consequently it increases with the increase of wind velocity. Because of this cooling effect of evaporation, too, wet soils are usually cold soils, for loss of heat by evaporation more than counterbalances the gain in heat absorbed by the soil water, so that the best percentage of water is the least amount that will just float the solid food and maintain the plants in a healthy state of turgescence.

Oxygen is as indispensable to the chemical life of the soil as it is to animal life. Both oxygen and nitrogen are essential to the biological processes, and both the chemical and biological activities in the soil are as indispensable to the crop as are sunshine and showers.

The importance of right proportions of water and air in the soil is further shown by the fact that the process of decay, whereby organic material is turned into humus and made available to the plant can not go on without an abundant supply of oxygen. A soil that contains too much water contains too little air. The ferments thrive best at a temperature of 85° to 95°, and when the soil contains from one-half to one-third the amount of water required for saturation. The ultimate source of the nitrogen found in vegetable matter is the air, and plants are unable directly to utilize it in a free state. The bacteria, which are chiefly concerned in maintaining the available supply of nitrogen in the soil, are able to work only during the warm seasons, and their activity depends directly on the temperature of the soil, being a maximum at 98°. On the other hand, light is inimical to the life and activity of these soil bacteria, a fact that may have some bearing on the rapid growth of corn during hot nights, inasmuch as the work of the microorganisms in feeding the roots is then facilitated. That corn germinates best at the high temperature of 98° to 100° is, undoubtedly, due to its tropical origin. For Professor Davenport shows that the attunement of plants to environment as regards temperature has its origin, not in processes of selection, but in the modifications of protoplasm by temperature itself.

Granted that the soil is porous enough and dry enough to admit the air readily, ventilation is facilitated by the unequal heating of night and day, and by nonperiodic temperature changes as well. As the air within the soil is heated it expands, and some of it is forced downward to the deeper layers; when it cools it contracts, and free air is drawn into the soil. The same effect is produced by barometric changes; the passage of areas of high and low pressure has been found to influence the flow of water from drains to the extent of 15 per cent, thus showing an unexpected movement of air in the soil. The corn belt lies entirely within the region of maximum frequency and intensity of barometric oscillations in the United States. Strong, and particularly gusty winds, by a measurable aspiratory action, have also a significant influence on soil breathing.

Climate, as has been said, is typified by the average meteorological conditions of a season; but these are all more or less periodic if not erratic. The best crops demand a permanence of certain conditions during a certain stage of growth; thus, for example, permanency of the moisture is called for, while rains supply it intermittently. Again, the root hairs developed in a dry soil seem unable to thrive in a wet one, and new rootlets must be thrown out to meet the new conditions. The same is true of rootlets developed in a wet soil; so that, in a soil whose moisture content fluctuates rapidly within a wide range, the plant is constantly taxed to maintain itself.

A regular supply of warmth is more genial than sudden transitions from heat to cold. Knowing these things it is the part of husbandry to ameliorate the eccentricities of the climate in order to improve the crop.

The effects of climate on the crop through the medium of the soil are classed as intermediate; but it will be seen that some of these effects are as truly direct as are the effects of sunlight and the temperature of the air.

Having seen how heat, light, moisture, and the supply of gases operate to control the supply of those ingredients that are furnished by the soil and that constitute in the main the ash of the plant, we return now to the immediate effect of these elements on the vital processes and assimilation.

The elaboration of the various elements that are found in a normal corn plant, of which there are about 14, takes place exclusively in the presence of the chlorophyl, or green matter of the leaves and stems, and only under the energy of sunlight. Heat alone is powerless to begin or to carry on this work, yet a relatively high temperature is nevertheless essential.

In the presence of sunlight the leaf pores, or stomata, open wide to admit a freer circulation of air in the blades. Of these pores there are in the blade of corn about sixty thousand to the square inch on the upper surface and ninety thousand on the under surface; their dilation and contraction and consequent control over ventilation and respiration is proportional to the intensity of sunlight, and hence very intense sunlight may of itself cause wilting independently of its heating effects.

The orange and yellow rays are the most active in the work of decomposing carbon dioxide; the relative energy of the different colors for this purpose correspond closely with their relative brightness.

While light is indispensable to the assimilation of carbon dioxide, it undoubtedly exerts a directly retarding influence on growth proper, or cell multiplication, but the beneficial effects of the higher temperature that accompanies daylight more than counteract this. The blue rays, opposing certain chemical changes, are those most effective in retarding growth. Sachs showed that for many plants when kept at a uniform temperature the rate of growth gradually increases during the night and is a maximum shortly after daybreak. This effect of light is opposed to the effect of the diurnal temperature; heat and light increase transpiration, which means a loss of water, and hence less growth. This sensitiveness and response of protoplasm to light is the result of the chemical changes wrought therein by the light.

By osmotic action the root hairs imbibe the liquid food that surrounds them; capillary and osmotic actions carry this supply to every part of the plant, to the tip of every blade, which is not only bathed in air, but has its microscopic interstices permeated with it. Here, in the leaf cells, the carbon dioxide of the air, which is practically an invariable quantity, comes in contact with the water that has been brought from the roots. Here, too, the energy of the ether waves, which we call light, but which the vegetable cell recognizes only as force, or a mode of motion, causes the carbon dioxide to part with some of its oxygen in exchange for some of the hydrogen contained in the water. Thus, there is formed within the cell a substance composed of carbon, hydrogen, and oxygen, the exact molecular structure of which is not known; in this process some of the oxygen is freed and thrown off by transpiration. By the introduction of the molecule of carbon dioxide into the cell the equilibrium in the atmosphere of that gas is disturbed and another molecule diffuses into its place; for this gas exists and behaves as if it were the only gas present in the space under consideration, the same law being true for each of the gaseous elements whose mixture constitutes what is called the atmosphere. The consumption of carbon dioxide tends constantly to produce a vacuum in the carbon dioxide atmosphere, and the law of diffusion as constantly tends to maintain the supply. If molecules of hydrogen are withdrawn from the fluid contents of the cell, instantly osmosis and diffusion tend to replace them; the same is true of the solid particles in solution. Assimilation within the cells of the leaves perpetually destroys the equilibrium of osmotic pressure, hence this pressure creates a constant flow toward the seat of demand. Evaporation from the leaves, which is proportional to temperature and is accelerated by winds, as is the supply of carbon dioxide, operates in the same direction, viz, to destroy the equilibrium in the leaf cells and channels, and consequently the tiny streams from the rootlets are hastened onward with their precious stores of food. Cold not only stiffens the sap and retards its flow, but also slackens molecular motion and hinders the chemical reorganization of the elements. The process of evaporation proper is, however, almost independent of the processes of nutrition, and is rather a "necessary evil." The most rapid growth frequently occurs under precisely those conditions that make evaporation least rapid.

The quantity of water that passes through the plant and is transpired and evaporated is enormous. The average is about three hundred parts of water to one of dry matter. According to experiments by Professor King of the Wisconsin Experiment Station, dent corn used three hundred and ten tons, and flint corn two hundred and thirty-four tons of water for each ton of dry matter produced. This same experimenter supplied growing corn with water as fast as it could be used to advantage, and found that the crop consumed during its season of growth water equivalent to a rainfall of 34.3 inches, and yielded more than four times as bountifully as a very large crop grown under the best natural conditions of rainfall in Wisconsin. And he concludes that "large as this movement of water is, it is seldom great enough to enable a moderately fertile field to produce its largest crops." And these tests in Wisconsin merely confirm a conclusion that is becoming quite general, and is prompting the advocacy of irrigation even in the humid regions. Moreover, the quantity of water producing a given result increases with the fertility of the soil, and, according to Wollny, the soil moisture produces its maximum results only when the plants are grown in the strongest light. The value of a given quantity of rainfall for the crop increases as the number of rains, and what has been called the useful remainder of rainfall is only 20 per cent of the total amount, percolation and evaporation accounting for 80 per cent. Percolation is a fertile source of loss of the valuable soil nitrates, especially in the wet fall and winter seasons, when the corn field is bare and a large proportion of the water escapes downward. Rain, like snow, is the "poor man's fertilizer," bringing down, per acre, in the course of a year, at Rothamsted, England, 24 pounds of salt, 4½ pounds of nitrogen, 18 pounds of sulphuric acid, and much carbon dioxide, which is a valuble solvent. A single drought late in July or August, during the critical period of tasselling or earing, has cost the Western States 100,000,000 bushels of corn. A wet harvest time results often in a dilute sap, and, consequently, a soft grain, which is the prey of microbes and fungi that thrive in dampness. These miscellaneous considerations show that in many unsuspected directions the question of moisture is a vital one, and that to husband it is the first duty of the farmer.

Some of the less important incidental relations of climate and corn, such as electricity, winds, frost, insect enemies, and diseases remain to be mentioned. Electricity artificially applied to the roots by charging the soil, and to the leaves by means of the electric light, have both repeatedly been found to stimulate the growth, and in some instances, greatly to accelerate it. Recent experiments show that when green leaves are exposed to direct sunlight there is developed a difference of electrical potential between the illumined and the shaded surfaces, amounting in some cases to .02 volt, but the bearing of this fact upon assimilation is not well known. Atmospheric electricity is a fertile source of ozone, or condensed oxygen, which is particularly active in the production of nitric acid. Electricity stimulates protoplasm, the ultimate vital principle, and may determine the character of its activities, but under natural conditions this element is believed to have but slight influence.

Winds have been called the vehicle of climate; but we are concerned here with their incidental and accidental features only. In the semi-arid regions broad, unprotected fields are frequently swept by high winds that remove two or three inches of the light surface soil, and with it the seed of the young crop. Strong winds during the period of maturity of the corn crop, especially after the roots have lost their vigor, by "lodging" the corn and subjecting it to the dangers of decay on the wet ground are often the occasion of great inconvenience, if not of serious damage. But the most remarkable immediate phases of this meteorological element are the hot winds that frequently ravage the corn belt west of the ninety-fifth meridian from Dakota to Texas. In 1888 ten Kansas counties reported an estimated loss of 21,000,000 bushels from this cause. These devastating blasts (fed by descending currents of air so hot and so dry as to abstract moisture faster than transpiration can supply it, and hence literally to burn the plants) are perpetuated by conditions of drought, and are most fatal during the critical stages of tasseling and earing. The moisture content of the soil and the nature of the winds have intimate reciprocal relations, and truly dessicating winds are improbable for any protracted period over a well-watered region.

Because it possesses such exceptional recuperative powers as to make it almost invulnerable to the hot winds of the semiarid west, it is worth while in this connection to mention kaffir corn, which the Department of Agriculture introduced in the early eighties from Africa, where it attracted attention on account of its peculiar drought resisting property, due largely to the fact that its roots penetrate to the depth of 18 or 20 inches.

While light frosts in autumn (by hastening maturity in a dangerous time) often prove wholesome, and while the value of the frosts of winter in disintegrating and preparing the soil for the subsequent crop is so well known as to require only a passing mention, on the whole the range of corn is much restricted and the crop imperiled by this element. Experts of the Department of Agriculture assure me that they regard it as quite probable that a kind of corn may ultimately be developed which will possess immunity from frost; but as yet the average interval between spring and autumn frosts virtually limits the growing season. The character of a winter may also affect the vigor and germinating power of the grain that is stored as seed for the subsequent crop.

Seasonal characteristics have practical connection, too, with the insect pests and diseases of corn. Not only during the crop season are these pests largely at the mercy of the elements, but fitful winters are sure to prove destructive to them, for during the bright, warm days eggs are hatched, chrysalides matured, and insects lured from their retreats, only to be caught and destroyed by the sudden cold waves. The fungus diseases, such as rust and smut, are carried by winds and are favored by wet seasons, dews, and moist atmosphere.

Many important facts bearing directly on the subject of this paper are found in the extensive report of 1891, above alluded to, by Professor Abbe, on the Relations of Climate to Crops. They will here be summarized, and while these deductions apply with equal weight to all annual crops, their importance is especially patent in the case of a crop with so extensive a range as corn.

Growing out of the interrelations of climates and plants there are two laws that admit of tolerably definite statement. These are the law of habit and the law of economy. Wherever the supply of heat is always sufficient the variations of moisture control, and wherever the supply of moisture is always sufficient the periodicity of heat controls the whole development of the plant. In other words, if the periodicity of heat is such as to warn of the necessity of economy, the whole life of the plant is determined by the course of heat, and the same for moisture. On the plains of South America, for instance, the dry season exerts the same influence as our northern winters. In the Middle States, not the rainfall of spring so much as what seems an instinctive knowledge of the approaching drought, stimulates the corn to a hasty development; at the north the growth is correspondingly accelerated by the knowledge of the rapidly approaching frosts of autumn. So sensitive is the plant to the changes of climate that even the ordinary seasonal irregularities have a strong influence; the general disposition acquired by the seed in a single dry or wet, warm or cold, early or late, season prepares it by virtue of that experience to become the best seed for planting in anticipation of another such season as that in which the seed was matured. This tendency is illustrated by the well-known fact that dwarfed varieties of corn from northern latitudes, when cultivated to the southward, mature earlier, are hardier, and more prolific than the native varieties. A corollary of great practical promise is that in a region habitually or frequently dry, corn raised in the driest years should be preserved for seed, as likely to be far better than any that may be brought from a distance. Hence the common, if not universal, practice of using seed grown in the preceding year is strongly condemned. By always utilizing seed that has been raised in the driest years one may hope speedily to develop varieties whose vegetating period will be so short that the crop will rarely be injured by the hot winds of July or August. And a similar rule would apply for any desired disposition we may seek to impress upon the seed.

In the light of these facts it is suggested that irrigation may come to be used as a temporary device to promote the evolution of new varieties that can be cultivated without irrigation. On the other hand, recent careful work in France has demonstrated that when the plants are forced to their maximum yield by irrigation the seed thereby suffers a marked deterioration, and that for continued maximum results the seed must be raised on dry soil.

Climate being inviolable and inexorable, what hope is there that the agriculturist shall be emancipated from the tyranny of frost and drought? Clearly, he must attain this by work on the soil and on the plant.

By utilizing vast stores of energy in the form of fuel man banishes the rigors of winter, thus creating artificial conditions of shelter and heat, by aid of which he has supplemented the process of acclimatization. Thus, also, must he cooperate with nature in behalf of the plant; he must combat her malignant aspects by intelligent selection; by scientific methods of culture he must supplement her beneficent efforts on behalf of the human race.

METHODS EMPLOYED IN THE DISTRIBUTION OF WEATHER FORECASTS.

By JAMES BERRY, Chief of Climate and Crop Division.

After making the most accurate prognostications practicable the Weather Bureau has no more important duty than to give them the most extended publicity that its facilities afford.

As with other classes of information the newspapers are the media for most effective work, and as every important newspaper in the country gives prominent place to the weather forecast, a dissemination is obtained so extensive as to be almost incalculable. The cities, towns, and thickly populated communities, through the newspapers have, therefore, not suffered for lack of weather information, but the rural districts have been less fortunate, and the devising of plans by which the agricultural classes might receive the forecasts in time to guide them in their daily avocations has been a difficult problem.

The Bureau since its establishment has from time to time considered many methods by which the forecasts might be made to reach the agricultural classes in time to be of use, and aside from the efforts of its officials, suggestions from others interested in the subject have been numerous. A vast majority of the latter, however, from one cause or another, have been impracticable, so that after the thirty years of experience the Bureau accomplishes its distribution of forecasts and special warnings principally through (1) the newspapers; (2) the system of telegraphic distribution, at Government expense, under direct supervision of Weather Bureau station officials; (3) the voluntary cooperation of railroad and telephone companies, public spirited citizens, and postmasters.

The organization of the local State Weather Services during the eighties tended to augment the interest taken in this subject and resulted in the adoption of the systems that now give to nearly every part of the country having mail or telegraph facilities, daily forecasts and warnings of unusual weather conditions.

The country has been divided into districts with a center of distribution for each, from which the forecasts are telegraphed daily, except Sundays and holidays, to subcenters for redistribution by telephone, mail, or railway bulletin service. The distributing points receive predictions by telegraph or telephone usually by 10:30 or 11 a. m., seventy-fifth meridian time, and the substations served by mail get theirs within a few hours thereafter, depending upon distance and mail connections.

Independent of the distribution attained through the press, there are now published daily more than 100,000 weather bulletins, much the greater part being in the form of postal cards printed from the telegraphic report received by postmasters at distributing points and sent to the outlying towns for display in suitable holders in post offices and other prominent places. Postmasters at distributing offices are largely relied upon in making this distribution. By a simple printing device the franked cards are rapidly printed in bold type, and the earliest mails carry them quickly to their destination. Logotypes are used, comprising a vocabulary of about 125 of the popular weather terms in which the weather forecasts are usually expressed. The forecast cards are stamped in a very expeditious manner, it being possible for one person to print several hundred cards within a few minutes. In the whole experience of the Weather Bureau no system has been tried that has proved more effective or inexpensive than this extremely simple method of stamping the forecasts by hand on postal cards bearing the official frank.

Other and older systems for conveying weather information have not been abandoned, viz, the flag displays and sound signals. The former consists of a series of five flags, which are displayed singly or in such combinations as to represent weather conditions. The sound signals are a code of steam whistle blasts which may be heard for miles in the country adjacent to the mill or factory sounding the same. This system is quite extensively used in some States, and has proved very popular. The code employed is the following:

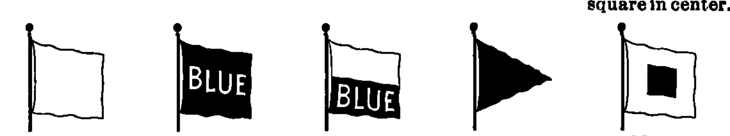
A warning blast of from fifteen to twenty seconds duration is sounded to attract attention. After this warning the longer blasts (of from four to six seconds duration) refer to weather, and shorter blasts (of from one to three seconds duration) refer to temperature; those for weather are sounded first.

Blasts.	Indicate.
One long	Fair weather.
Two long	Rain or snow.
Three long	Local rain or snow.
One short	Lower temperature.
Two short	Higher temperature.
Three short	Cold wave.

By repeating each combination a few times, with intervals of ten seconds, liability to error in reading the signals may be avoided.

EXPLANATION OF WEATHER FLAGS.

No. 1. White Flag.	No. 2. Blue Flag.	No. 3. White and Blue Flag.	No. 4. Black Triangular Flag.	No. 5. White Flag with black square in center.



Clear or fair weather.	Rain or Snow.	Local Rain or Snow.	Temperature.	Cold Wave.

When number 4 is placed above number 1, 2, or 3, it indicates warmer; when below, colder; when not displayed, the temperature is expected to remain about stationary. During the late spring and early fall the cold wave flag is also used to indicate anticipated frosts.

Quite a variety of methods other than the aforementioned have been tried from time to time, some giving much satisfaction, among which may be mentioned the plan of attaching to letter boxes a suitable frame, the card forecasts being placed therein by the letter carriers in making their rounds for the collection of mail. This system is in vogue in several cities and is very popular. The street cars are also used to a considerable extent, the forecasts being posted in the interior of the cars in bulletin form, and in some instances symbols representing the flags are displayed from the sides or tops of the cars.

Within the year 1900 there has been utilized what now promises to be one of the most effective methods of reaching the agricultural classes, viz, the rural free mail service. Wherever it has been possible to reach the distributing post office with the telegraphic forecasts in time to catch outgoing carriers the service has been given to farmers along their routes. By this means it has been possible to place in the hands of more than